Attachment A 1381

With best regards
Michael Rozengurt

P.S. Your comments or critique will be very appreciated.
Misha

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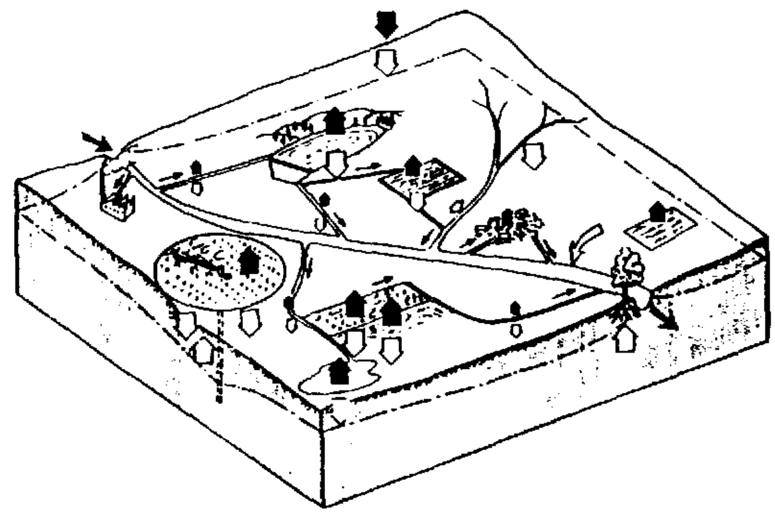

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Hubert J. Morel-Seytoux

period of 50 to 60 years (as a rule, this period includes two typical cycles and four phases of runoff variables).

***Impaired runoff** (regulated runoff)* - is a stream flow subjected to the impoundment, its regulated values describe a hydrological "mixture" of two regimes: stochastic (natural) and deterministic, i.e., modified by the impoundment and storage releases. Impaired river runoff cannot be subjected to stochastic analysis, but can serve as an estimate of availability or depletion of fresh water if it compares with unimpaired runoff (the same approach can be used to analyze the chemical and biochemical changes brought about by modification of runoff).

Cumulative losses of runoff - the integrated water deficit sustained by a given river's watershed due to water withdrawals to dams and water conveyance facilities, or both. Note that the period of maximum accumulation of diverted waters appears to be early spring-beginning of summer (March-June) i.e., the most essential a span of time of ascending biological activities in coastal ecosystems (in subtropical areas it may shift to late summer-fall).

Cumulative impact - *is an integrated aggravation of physical and chemical* and biological properties of water bodies desiccated by dams that may *facilitate the impoverishment of ecosystems in a way not seen under* unimpaired conditions.

Delta water body - is a specific buffer zone which tends to repel salt intrusion and maintain dynamic equilibrium between the river and sea (estuary); note that delta outflow is responsible for production, processing, circulation and discharges to an adjacent basin more than two-third of the biochemical organic and inorganic load. In addition, the delta serves as a filter of natural and man-induced pollutants into a coastal environment, and provides for the most productive interface for migration, breeding, spawning and feeding of numerous estuarine-coastal zone species of fish and shellfish.

Estuary - the intermediate, dynamic and cumulative link between a river(delta) and coastal sea where continual variable confluence, interaction and mixing processes between fresh and brackish outflow and seawater inflow maintain the four zones of mixed water masses separated by a visible (through color) demarcation lines known as a hydrofront. The redistribution of *hydrophysical and biochemical* properties between the zones provides for the unique, highly productive, diverse and resilient organisms.

Coastal seas - *are the most productive, vital shallows of the world ocean* that encompass the area down to the upper boundary of the continental slope of 200 meter depths. Their hydrophysical and biological regime are conditioned by the combined effect of river and estuarine brackish water buoyancy (entrainment, mixing, and transport), tide (mixing), and wind (mixing and transport). Under unimpaired conditions this zone is capable of maintaining a quasi- equilibrium, "homeostasis" condition

36. Rozengurt, M. A., 1991. "Strategy and ecological and societal results of extensive resources development in the South of the USSR". In: Proc. The Soviet Union in the Year 2010. U.S. AIA and Georgetown University, *Washington, D.C. p.p.119-137.*
37. Rozengurt, M. A. and I. Haydock., 1991. "Effects of fresh water development and water pollution policies on the world's river-delta-estuary-coastal zone ecosystems". In: H.S. Bolton (Ed.) Coastal Zone '91' Proc. of the Seventh Symposium on Coastal and Ocean Management. American Society of Civil Engineers, New York, NY. pp. 85-99.
38. Rozengurt, M.A., 1992. "Alteration of freshwater inflows". In R. H. Stroud (Ed.) Stemming the Tide of Coastal Fish Habitat Loss. Marine Recreational Fisheries Symposium. National Coalition for Marine Conservation, Savannah, GA. pp. 73-80.
39. Rozengurt, M. A. and I. Haydock, 1993. "The role of inland water development on the systemic alteration of the coastal zone environment". In: Proc. of Watershed '93. National Conference on Watershed Management. US.E.P.A., Washington, DC.
40. Rozengurt, M. A. and I. Haydock, 1993. "Freshwater Flow Diversion and its Implications for Coastal Zone Ecosystems". In Transactions of the 58th North American Wildlife and Natural Resources Conferences. *Washington DC. pp. 287 - 295.*
41. Rozengurt, M.A. and J. W. Hedgpeth. 1997. "Distortion of thermodynamic equilibrium of watershed coastal seas' ecosystems". In With Rivers to the Sea. Interaction of Land Activities, Fresh Water and Enclosed Coastal Seas. Joint conference 7th Stockholm Water Symposium and 3rd International Conference on the Environmental Management of Enclosed Coastal Seas (EMECS). 10-15 August. Stockholm. Sweden. pp. 182-184.
42. Sokolov, A. A. and T. G. Chapman.(Eds.), 1974. Methods for Water Balance Computations: An international guide for research and practice. The UNESCO Press. Paris.
43. Yevjevich. V.,1982. Stochastic Processes in Hydrology. Water Resources Publications. Littleton. CO.
44. Zaitsev, Yu. And V. Mamaev, 1997. Biological Diversity in the Black Sea. A study of change and decline. United Nations Publications. New York.

Appendix 1.

Some important definitions for understanding watershed-coastal zone ecosystem functioning.

Natural river runoff (unimpaired) - the net drainage basin runoff whose daily, monthly and annual fluctuations are determined by geomorphometric and geophysics limitations of watershed and stochastic nature of major freshwater balance elements (rainfall minus evaporation, transpiration, and percolation). The unimpaired flow characteristics are computed over a

Running on entropy: the effect of water diversions on the estuary - coastal ecosystems.

Michael A. Rozengurt, Ph.D., P.H., Coastal Consulting, 8888 Lauderdale Court, Unit 216F, Huntington Beach, CA 92 646; Ph. (714) 536 - 4403; E-mail: mrozengurt@Juno.com

Abstract.

Estuarine systems are parts of the shelf of a world ocean where contact and interaction between plants and animals and their environment occurs tens to hundreds of times faster than in other areas of land and water. Historically, *unobstructed* water and salt exchange between rivers and their adjacent seas preserved a rather intricate, quasi-equilibrium regime of estuaries. For fresh water fluxes serve as a physical barrier which repulse brackish or salt water intrusion into a delta. The seasonal alteration of runoff potential/kinematics energy input/output exerts a substantial force on deltaic, estuarine, and coastal circulation patterns (example: a river plume, an estuarine hydrofront). The stronger the unimpaired runoff, the higher its energy output. The latter accelerates a substantial horizontal and vertical mixing and a powerful frictional drag. Subsequently, these processes perform a critical flushing of estuaries. In any given season or year, these mechanisms determine a spatial-temporal distribution of hydrophysical and biological properties of estuarine habitats. The former serves as nursery and breeding grounds for many commercially important species of fish and shellfish directly or indirectly estuarine *dependent*.

However, since 1930s-1950s, the systematic truncation and depletion of spring and annual runoffs due to the impoundment in excess of ± 30% *plus of its norms* have led to the predominance of subnormal wetness or even droughts conditions. In addition, cumulative, perennial losses of millions of acre feet of water has facilitated an inverse redistribution of impaired runoffs' remnants (minimum in spring, maximum in fall). This development has exacerbated the aggravation of estuaries-coastal seas' ecosystems and impeded a normal river continuum to coastal seas. Subsequently, reduction of millions of tons, of organic and inorganic matter, oxygen, sediments have followed that further plagued or nearly eliminated the valuable fishery along the U.S. Pacific and Atlantic coasts, Mediterranean Basin, and others. To be precise, today mankind is witnessing a global birth of new, artificial ecosystems, namely": **impounded estuaries and coastal seas."** Two major factors have contributed to the despoliation of habitats of coastal embayments, namely: the ignoring of the importance of a normal river *continuum to coastal* ecosystems' survival and methodical shortcomings of today's unimpaired / impaired river runoffs' studies. These and other topics are briefly discussed in the following presentation.

Introduction: consideration for river-delta-coastal sea ecosystems management.

Among numerous coastal embayments, estuaries play special roles on the adjacent coastal seas' environment and have been clearly recognized by mankind since time immemorial. By definition, **estuaries are dynamic, critical links within the delta-sea ecosystems where continual variable confluence, interaction, and mixing between river and sea take place.**

Under natural setting the kinematics energy of unimpaired river runoff preserves the specific regime of estuarine systems through the balancing exchange of a definite ratio of volumes and properties of four interactive zones which are strictly defined (Venice International classification of 1958) by the range of salinity from fresh to brackish to salty sea water, and other accompanying physical and chemical and biological *characteristics(Almazov, 1962, Lauff,1967). The average salt concentration* of 5.0 g/L is considered a critical natural barrier for strictly estuarine species at early stages of their development within the avante-delta zone bounded on the deltaic side by a river hydrofront whose salt concentration may vary from 0.1 to 0.5 g/L (Khlebovich, 1974).

These and other natural combinations of regime characteristics cultivated migration routes, spawning and nursery grounds for the life stages of a unique diversity of estuarine-dependent species, some commercially important fish and shellfish (Chambers, 1992).

However, despite having evolved strong physiological mechanisms to ensure their survival and the highest biological productivity, even hardy estuarine living species have tolerance limits to prolonged exposure to extreme, non natural conditions particularly of those caused directly or *indirectly by the Five "D-words" dams, diversions, dewatering, deforestation*, and *desertification*--the 5 Ds (Rozengurt and Haddock, 1993, Figure 1).

The western Pacific and central and south Atlantic estuarine - coastal biota has experienced the effect of the 5Ds with frightening similarity to the impoverishment of the eastern Mediterranean sea (the Nile River delta since 1965) as well as the Black, Caspian, Azov, and Aral Seas since 1970s. Taken together, these are signals from nature that must be heeded at our greatest future peril (Halim, 1991, Rozengurt and Herz, 1981, Rozengurt and Hedgpeth, 1989, Rozengurt and Haydock, 1991, Rozengurt, 1992).

The laws of conservation of mass and energy state that mass and energy neither can be created or destroyed. They can be transformed from one form to another but the total energy output will be constant (Fig. 2). For example, a cascade of dams transforms an unimpaired runoff energy into the following regulated energy components: electricity, + heat, + mechanical energy, + crops energy, + remnants left an unusable volume of water

19. Mann, K. H. 1982. Ecology of Coastal Waters, a Systems Approach. Berkeley, CA, UC Press.

20. McCully, P., 1996. Silenced Rivers. The Ecology and Politics of Large Dams. Zed Books. London & New Jersey

21. Micklin, P.P., 1994. "The Aral Sea Problem". Proc. of the Institution of Civil Engineers. Civil Engineering. August.

22. Naiman, R.J.(Ed.). 1992. Watershed Management. Balancing Sustainability and Environmental Change. Springer Verlag, NY.

23. National Research Council (NRC), 1992. Restoration of Aquatic Ecosystems: science, technology, and public policy. National Academy Press. Washington, D.C.

24. NRC, 1994. *Environmental Science in the Coastal Zone:* Issues for further research. National Academy Press. Washington, D. C.

25. Officer, Ch.B., 1976. Physical Oceanography of Estuaries (and Associated Coastal Waters). John Wiley @ Sons. New York.

26. Petts, G. E., 1984. Impounded Rivers. Perspectives for Ecological Management. John Wiley & Sons. New York.

27. Ratkovich, D.Ya., 1993. Hydrological Principles of Water Supply. Russian Academy of Sciences. Moscow.

28. Rozengurt, M.A.,1971. Analysis of the Impact of the Regulated River Runoff on Salt Regime of the Dniester Estuary. Naukova Dumka (Scientific Thought). Kiev, Ukraine. U.S. Library of Congress, GC12LR 6.

29. Rozengurt, M.A., 1974. Hydrology and Prospectives of Reconstruction of Natural Resources of the Northwestern Black Sea Estuaries. Naukova Dumka (Scientific Thought). Kiev. Ukraine. U.S. Library of Congress, GB2308/B55R69

30. Rozengurt, M. A. and D. M. Tolmazin, 1974. "Methods of computation of the salinity regime in limans, lagoons, estuaries and shallow seas in connection with water consumption for commercial requirements". II Colloquy International sur L'Exploitation des Oceans" Bordeaux, France. pp.1-6

31. Rozengurt, M. A. and M. J. Herz.,1981. "Water, water everywhere but just so much to drink" Oceans. V 65-67.

32. Rozengurt, M. A., M. J. Herz, and M. Josselyn., 1985. "The Impact of Water Diversions on the River-Delta-Estuary-Sea Ecosystems of San Francisco Bay and the Sea of Azov". In: D. L. Goodrich (Ed.) San Francisco Bay. Estuary-of-the-Month. Seminar Series, 6. NOAA. Washington, D.C. pp.35-62.

33. Rozengurt, M. A., M. J. Herz, and S. Feld.,1987a. Analysis of the Influence of Water Withdrawals on Runoff to the Delta-San Francisco Bay Ecosystem. Tech. Report No. 87-7. Center for Environmental Studies. San Francisco State University (SFSU). Tiburon, CA.

34. Rozengurt, M. A., M. J. Herz, and S. Feld. ,1987b. The Role of Water Diversions in the Decline of Fisheries of the Delta-San Francisco Bay and other Estuaries. SFSU. Tech. Report No. 87-8..

35. Rozengurt, M. A. and J. W. Hedgpeth., 1989. "The Impact of Altered River Flow on the Ecosystem of the Caspian Sea". Reviews in Aquatic Sciences V. 1. 2. pp. 337-362.

References

1. Almazov, A.M. 1962. Hydrochemistry of Estuaries. Pub. Academy of Science of U.S.S.R., Kiev.
2. Baker, B. 1994. "Aquatic systems a concern as the government relicenses dams". Washington Watch. June.
3. Bowden, K.F. 1983. Physical Oceanography of Coastal Waters. Ellis Horwood Limited. Chichester.
4. Chambers, J.R. 1992. "Coastal degradation and fish population losses". In: R.H. Stroud (Ed.) Proc. of the Symposium on Coastal Fish Habitat Conservation. Baltimore, MD. pp.45 - 53.
5. Clark, J. and N. G. Benson. 1981. "Symposium Summary and Recommendations". In: R.D. Cross and D.L.Williams (Eds). Proc. of the National Symposium on Freshwater Inflow to Estuaries. *Vol. II.* Dept. of the Interior. Washington, D.C.
6. Cloern, J.E. and F. H. Nichols, 1985. *Temporal Dynamics of an Estuary:* San Francisco Bay. Dr W. Junk Publishers.
7. Ellis, W., 1990." *The Aral, A Soviet Sea Lies Dying*". National Geographic Feb.
8. Elpiner, L. I. 1991. "Medical - Ecological Problems in the eastern Aral Region". Water Problem Institute of the Acad. of Science of U.S.S.R. Moscow.
9. GESAMP. 1992. "The State of the Marine Environment". Intergovernmental Oceanographic Commission. Blackwell Scientific Publications, London. pp. 22-23.
10. Haan, Ch. T. 1982. Statistical methods in Hydrology. The Iowa State University Press. Ames.
11. Halim, Y. 1991. "The Impact of Human Alterations on the Hydrological Cycle on Ocean Margins". In: R.F.C. Mantoura, J.M., Martin and R. Wolast (Eds.) Ocean Margin Processes in Global Change . John Wiley & Sons Ltd. pp. 301-327
12. Hedgpeth, J.W. 1977. "Seven Ways to Obliteration: factors of estuarine degradation". In Proc. *Estuarine Pollution, Control and Assessment.* EPA. Washington, D.C., 2, pp.705-713.
13. Hinman, K. 1991. "*No Habitat, No Fish*". *Marlin.* November. National Coalition for Marine Conservation. Savannah, GA. pp. 110-112.
14. Kemp, W. M., A Yanez-Aranciba., E. Goldsmith.. and N. Halyard. 1984. The Social and Environmental Effects of Large Dams. Sierra Club Books. San Francisco
15. Kennish, M.J., 1986. Ecology of Estuaries. CRC Press. Boca Raton. Florida.
16. Lauff, ,G.H. (Ed.), 1967. Estuaries. AAAS publication. Washington. D.C., No.87, pp.37-44.
17. Leopold, L. B., 1994. A View of the River. Harvard University Press. London.
18. Luchsheva, A.A., 1978. Practical Hydrology. Gidrometeoizdat. Leningrad.

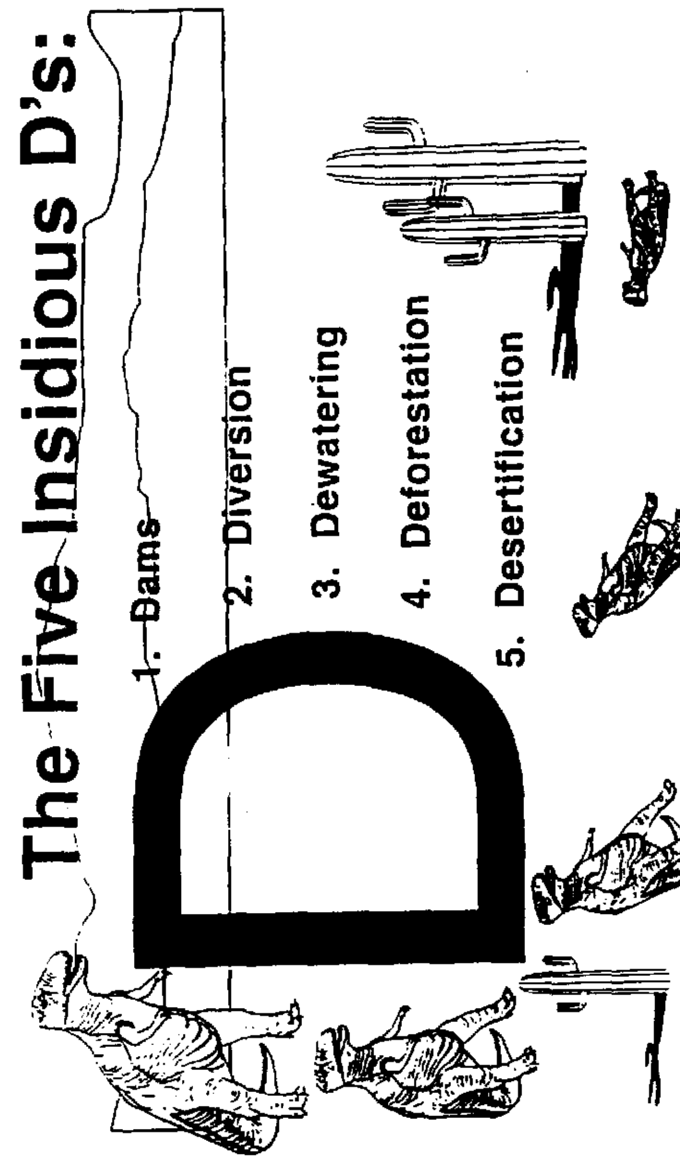

Figure 1. GOING HOLISTIC: Watershed Management

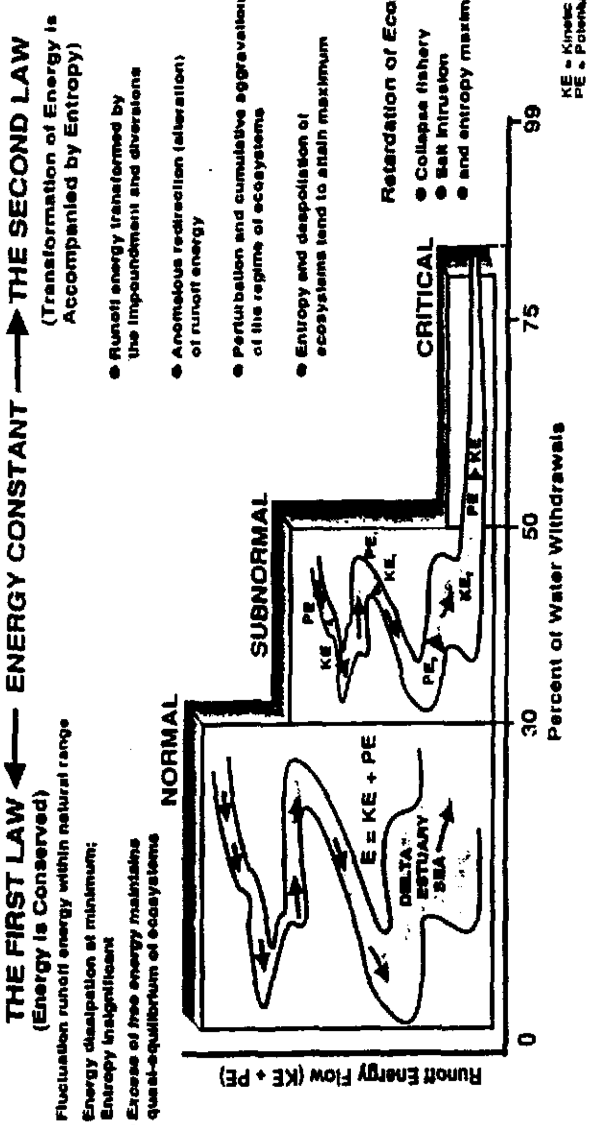

Figure 2. Application of Laws of Thermodynamics to river-delta-estuary-coastal sea ecosystems.

Table 1. Irrevocable distortion of river-delta-estuary-coastal ecosystem

WATERSHED MODIFICATION		RESULTS
Artificially abnormal runoffs regardless of precipitation; Nature's margin - 25%.	1 →	Deleterious for water quality and living resources.
Truncated flooding and duration, abnormal runoff distribution	2 →	Obstruct normal migration and spawning; river-coastal zone no longer natural.
Cumulative runoff losses exceed many times delta and estuarine volumes.	3 →	Loss of million tons of silt, organic and inorganic matter, oxygen depletion, salinization of wells and aquifers.
Dewatering of the delta, abnormal water level fluctuations, temperature and oxygen shock; decreased runoff velocity and self-purification; increased detention time.	4 →	Desertification, salinization, scouring, and erosion of delta, beaches; subsidence of levees; accumulation of pollutants. Fresh water intakes are in jeopardy.
Runoff deficiency aggravates estuarine-coastal processes (advection, mixing, entrainment, enrichment, etc.).	5 →	Compressed salt wedge maximum; delta salt contamination, oxygen deficiency; eutrophication/loss of productivity.
Transformation of stochastically balanced ecosystem into unbalanced waterbodies	6 →	Despoliation of coastal ecosystems on catastrophic scale. Agricultural discharges exacerbate this problem.
Estuary transforms into marine harbor controlled by tides and wind-driven circulation.	7 →	Catastrophic decline of fish reproduction, survival and catch, spawning grounds demolished. Coastal zone becomes a "blue desert."

INSURMOUNTABLE ECONOMIC AND SOCIETAL LOSSES use and led to increasingly severe environmental, economic, and societal losses of 1980's and 1990's, especially when severe droughts had occurred.

Conclusion. The long entrenched attitude toward maximum use of watershed runoffs has been based on the erroneous assumption that a river flow would never be a limiting factor on agricultural and urban growth, or have any serious impact on the deprivation of the delta - estuary - coastal seas' environment. *This strategy, in concert with the application of* incorrect or single-minded methods to water availability studies, has further *exacerbated the contradictory effects of man- induced extremes* in rivers' by dams cascading and deltas' dissecting by water conveyance facilities (Table 1).

Insurmountable problems have led to insidious increase of entropy in similar systems the world over. For too long we have failed to understand the intrinsic nature of watershed-estuarine ecosystems, and have blamed a multitude of sins (pollution, overfishing, and now, arguably, global warming) for the precipitous decline of the catch of estuarine- depended, directly and indirectly, species of fish and shellfish and other resources. However, now it is time to focus on the limitation of river flow for withdrawals, for it is the fresh water that forged and strengthened the critical link between rivers and bordering coastal seas over the past several thousand years.

Acknowledgment. *The author greatly appreciates the unfailing support* and scientific understanding of Dr. Irwin Haydock, former Manager and Chief *Scientist of Orange County Sanitation Districts, in completing* this manuscript. Special thanks to Hai Nguyen for assistance in preparing drawings.

trapped behind the lowest level of a dam, or retained in an irrigation network, and + the energy remnants of a depleted delta runoff that finally discharge into coastal water. Therefore, a significant runoff energy accumulation, redistribution, and dissipation in upper and middle network of impounded rivers occur.

In this case, the energy of impaired deltaic runoff cannot generate the work necessary to preserve the estuaries from the deterioration of their geophysical properties and biological productivity's. *Unarguably, if* excessive use of river networks continues to disregard the postulates of the second Law of Thermodynamics (Leopold, 1994, Rozengurt, 1994, Rozengurt and Hedgpeth, 1997), then entropy will tend to reach the *ultimate maximum* (Figure 2).

For example, a large percent of the Sacramento-San Joaquin river watershed's runoff energy is consumed by 155 federal, state and local dams (a total of in California 1,200 reservoirs) and water conveyance facilities of the State Water Project (the California Aqueduct) and the Federal Central Valley Project (Delta-Mendota Canal). The annual runoff accumulation in the major dams amounts to 70% of a perennial norm of 28 million acre-feet ($34 km^3$) (Rozengurt et al., 1987a). Hence, runoff energy has decreased an amount nearly equal to the unused energy trapped behind the dams or diverted in water conveyance facilities. These man-induced happenings may be comparable to ecological cataclysms of past measured by variable entropy.

Some scientific and managerial assumptions in watershed development affecting coastal embayments and seas.

There are four major, regime-sustaining features whose unimpaired interaction has made estuaries what they are(Rozengurt, 1992), namely: (1) stochastic behavior of unimpaired runoff; (2) an ecological river continuum into the coastal sea; 3) quasi-dynamic equilibrium of estuarine ecosystems, and (4) limited biochemical resilience and tolerance of estuarine biota toward natural extreme regime disturbance. The following is some explanation of those features which can shed light on the mechanism of estuarine survival whose needs sometimes are obfuscated in water planning and management.

First. Two different methods of applied hydrology are used to study runoff's behavior: stochastic, for unimpaired values of runoffs; and deterministic, for impaired values after water development(Haan, 1982, Ratkovich, 1993, Yevjevich, 1982). (Note that stochastic values of precipitation and evapotranspiration in concert with the morphometric, morphologic, and geophysics properties of watersheds mold unimpaired runoffs Appendix 1).

The stochastic method can be used to determine unimpaired, seasonal and perennial norms (computed over 55 to 60 years), and the probabilities of occurrence of runoff statistics, and frequency histograms (Sokolov and Chapman, 1974). These characteristics serve as a basis for the classifications of wetness-of-the year, calculating water balance of estuaries, planning water availability for diversions, and determining ecological limitations of water withdrawals, etc..

By definition, unimpaired, average monthly, seasonal, and annual runoffs whose volumes exceed some percentage of norms can be designated as historical, critical, abnormal, wet, or normal years. On contrary, if runoffs are less than norms then they can be classified as a subnormal, dry, critical dry, and drought year (Luchsheva, 1978). Unarguably, the rank of wetness is the key element for decision-making about the compatibility between ecological needs of an estuary and planning for water diversions.

By use of this method, the author determined that the predominant natural deviations of annual and spring unimpaired runoffs for successive five running years have been exemplified by the range ±25 to 30% of the corresponding norms (Clark and Benson, 1981, Rozengurt, 1971, 1974, Rozengurt and Hertz , 1981, Rozengurt and Haydock, 1993, Rozengurt and Hedgpeth, 1989). This was subsequently found to be the case for the Dnieper, Dniester, and Danube (Black Sea), Don and Kuban (Sea of Azov), Volga (Caspian Sea), Columbia, and Sacramento-San Joaquin (western Pacific, Figure 3 and 4), Nile and many other rivers (GESAMP, 1992, Rozengurt et al., 1985, 1987 a, b, Rozengurt, 1991, 1992).

Over this time span, the deterministic method has been used to estimate the statistics of impaired runoffs. Then, by tuning their absolute averaged values to the frequency curve of occurrence of unimpaired runoffs, one can evaluate their stochastic significance for non-impounded conditions of deltaic - estuarine systems. This latter comparison is of paramount importance for it can provide necessary hypothetical interpretation about significance of runoffs' remnants in maintaining coastal embayments. In addition, the subtraction of an impaired runoff from unimpaired and appraise perennial monthly and annual cumulative losses of runoff sustained by river-coastal seas due to water withdrawals.

For example, in the Delta and San Francisco Bay and the Columbia River the predominant deviations of impaired flow (successive impaired runoff for five running years minus a norm) varied from spring unimpaired norms from -35 up to -85 or more per cent over the same period (Figure 3, May). Note that due to discharges from irrigation network or sanitary releases, or both, late summer-fall residual runoffs can be nearly equal or higher then the spring regulated runoff. Yet, this new feature has failed to improve biological productivity for this abnormal regime phenomenon and, besides, its laden with agricultural pollutants and salt

regulated runoffs render erroneous randomness of wetness. This mutes and underestimates the adverse effects of runoff fragmentation on the estuarine-coastal sea environment; (5) impaired flow "standard" and "criteria" were not aligned to their would be probabilistic of unimpaired runoffs. Therefore, they were deprived their stochastic and ecological significance. This made their guardian value for protecting estuaries groundless; (6) failure to incorporate the cumulative losses of runoff and its physical and chemistry elements in estimation of their impact on salt balance and living resources of coastal ecosystem; and, (7) failure to apply the postulates of the First and Second Laws of Thermodynamics to foresee the critical limit of the impoundment whose excess will lead to decrease of the delta outflow and a total runoff energy to the point of destructive depletion. As a result, that signifies entropy maximum as a governing factor of the deprivation of estuarine-coastal sea ecosystems. As those bright fellows Sir Isaac Newton and Dr. Albert Einstein taught, you can't get something from nothing!

These major scientific shortcomings in water sustainability studies have made it nearly impossible to execute reasonable prognosis and provide rational recommendations concerning water diversions or how to maintain a suitable ecological continuum from rivers into coastal ecosystems.

Managerial shortcomings. Over the past several decades some political and economic requirements have been adopted to justify nearly unlimited water development. Planners and some scientists have failed to acknowledge that there are "essential and intimate" links between rivers and their coastal embayments' environment. Instead, the call to a single-minded determination: "let us build the network of dams first and see what happens" or "not one drop of fresh water to the sea should be wasted" has prevailed since the 1930s. As a result, these misguided rationale have led to: (1) multi-faceted use of watersheds based on purely political or economic grounds, or both; (2) balanced optimization alternatives of water development and preservation of a river continuum not being given equal weight at any stage of impoundment (McCully, 1996); (3) total economic and societal appraisals of natural watershed runoff drawbacks not being discussed in terms of a regional limit for population, industrial, and agricultural growth, as well as of human needs for aesthetic expression (Naiman, 1992, NRC, 1994), and, (4) an antithetical faith that river surface and groundwater supplies are inexhaustible and their deltas should be considered as a convenient plumbing conduit rather than as the heart of riverine - deltaic- estuarine -coastal sea ecosystems.

It is all too evident, the lack of understanding of the fact that runoffs are a strategic resource of river beds and adjacent ecosystems has led to their dewatering and chronic impoverishment. Worse, decision-making has denied the necessity of aligning the long-term planning and development of a multi-faceted infrastructure to the natural randomness and limitations of runoff to be diverted. Consequently, some water supply excessive gains of 1950's-1970's have sadly misconstrued the compatibility of different water

Scientific wanderings. By the mid-1990's, when impoverishment of the delta - *estuary -coastal sea ecosystems have* spread the world wide, it has become fashionable to mouth the "holistic approach to ecosystem management" or "refined sustainability." These philosophical and, in some degree, poorly defined concepts assume actions are aimed to develop and integrate a broader vision on the balanced planning, management, and enhancement areas where rivers meet seas. However, these multifaceted attempts may be too late to salvage even the remnants of a natural watershed-coastal continuum, especially where engineers, planners, and policy makers continue to exhort that not a single drop of fresh water should be wasted to the sea.

Needless to say, that 75000 relatively large dams (higher than 8m) and 2.5 million small dams now operating in U.S. (National Research Council, 1992). Not counting hundreds of world wide gigantic dams ,reservoirs, and thousands of hundreds of miles of water conveyance facilities whose capacity are responsible *for irrevocable diversion up to* 30 to 90% of seasonal flooding. Subsequently, for some estuaries and adjacent coastal seas irrevocable fresh water losses to for the last three decades have ranged from nearly 550 km ^{3} in San Francisco Bay and the Gulf of Mexico to some 1500 km^3 to each of Black, Caspian and Sea of Azov, the Nile River Delta and Columbia River coastal zones.

In point of fact, today's unrealistic models of water planning display unawareness of the scope and limitations of river watersheds to water withdrawals and apathetic indifference of nature's documented needs. This case was made eloquently by Joel Hedgpeth (1977). In addition, several major assumptions might be considered to be responsible for the current precarious state of coastal embayments can be named: (1) failure to recognize that there are nearly universal, well-defined, predominant range of natural runoffs' fluctuations of about ±25 up to ±30% of the perennial spring and annual norms computed for the period of 55 to 60 years that provide the key ranges of water available to man; (2) the impaired flows can not be used in probability analysis of wetness of year, nor for water availability studies, for it incorporates only "vestiges" of the historical randomness of *the unimpaired flows and, therefore, violates the classical* rules of stochastic hydrology; (3) the same also applies when the mixed *time series database, i.e., pre-project,* stochastic and a post- project, deterministic flows are wrongly analyzed together as historical (Cloern and Nichols, 1985). Such mistaken evaluations of runoff are typical for some biological and water availability studies, and, as consequence, the planners see a rosy picture in water supply where in reality is pronounced water deficit. Note that the deviations of impaired discharges of their perennial norms are much less than those computed from the unimpaired norms. This is also true when the perennial norms were obtained from a mixed database, i.e., pre - and past-project river runoffs; (4) as a rule of a thumb, more often then not the impaired discharges during recharges of dams are several times less than, otherwise, unimpaired flows. And, therefore, the statistics

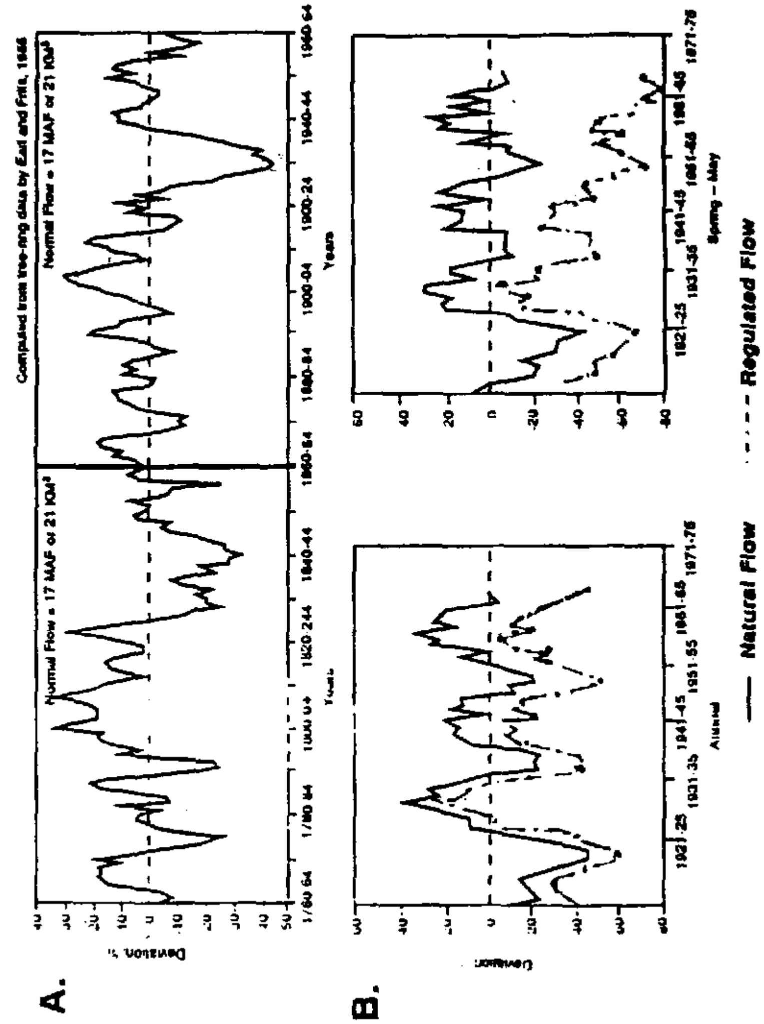

Figure 3. A.) Deviation of the 5-Year running mean combined four river runoff of normal for 200 years. B.) Deviation of the 5-Year running mean runoff of normal to San Francisco Bay.

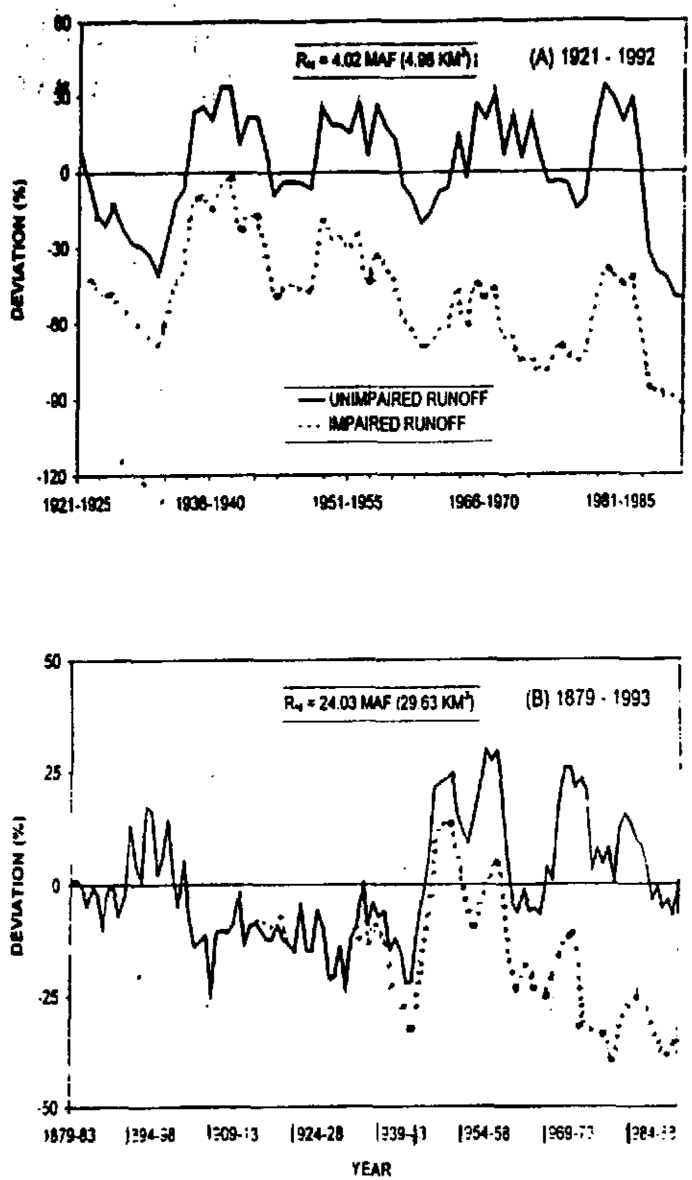

Fig. 4 Deviations (%) of Five Year Running Mean May Unimpaired and Regulated Outflow of (A) Sacramento-San Joaquin Delta and (B) Columbia River

In this regard, according to B. L. Bandurski (International Joint *Commission, personal communication*),"**the reality of watersheds populated (relatively recently) by humans is one which (1) the whole system memory is of runoff that was unimpaired in terms of the system's optimal operation, in which (2) the human memory is an incomplete process subsystem, and in which (3) much of the general environment of this "embodied memory" (matter/energy and information in all its indigenous forms) is now composed of impaired runoff.**".

This unnatural process has led to a gradual increase of entropy that signifies an ecological instability of impounded water system and elimination of ingenious biota, valuable fish and shellfish - for all attempts to restore the fisheries have failed - the current habitats have nothing in common with their teeming past. Hence, the impeded functioning of deltas and, finally, the entire river continuum has wrought the birth of new, artificial ecosystems on a global scale, namely: **"the impounded river-delta-estuary-coastal seas."**

These phenomena have entirely materialized in the last two decades and have nearly eliminated: 1) stochastic nature of runoff; 2) quasi-dynamic equilibrium of water and salt exchange among different ecosystem links; 3) a river continuum into coastal sea; and 4) ecological tolerance of habitats.

For example, in the former U.S.S.R., within just twenty years, all southern estuarine-coastal seas ecosystems had been nearly transformed to a blue desert. Among them, the Aral Sea has ceased to exist, for since 1970s impaired inflows to the sea have been much less then the evaporation, except in rare and unusually wet years. Moreover, the salinity of its remnants, precipitously shrinking water body had multiplied up to four to six times (Ellis, 1990, Micklin, 1991). Salt dust and toxins blown from the more than 65% of dry sea bottom fell back to earth and destroyed crops and habitats for hundreds of miles downwind. Contamination of drinking wells makes the infant mortality in the surrounding watershed nearly five times the Russian average - a staggering 10 to 20% of all babies born (Elpiner, 1991).

Economic losses for the fishery revenues in southern seas of a former Soviet Union alone have amounted up to several billion dollars per year: with thousands of fishery boats and hundreds of thousands of professionals out of work. Oddly enough, but between 1963 - 1994, according "United Anglers Update" (April, 1994), the most productive estuary on the West Coast of the American Continent (the Delta-San Francisco Bay) "sustained nearly $5 billion losses in the sport and commercial fishing industries" due to the California "state's failure to equitably share the public's water". And, in addition, "it ruined many small business and put thousands out of work".

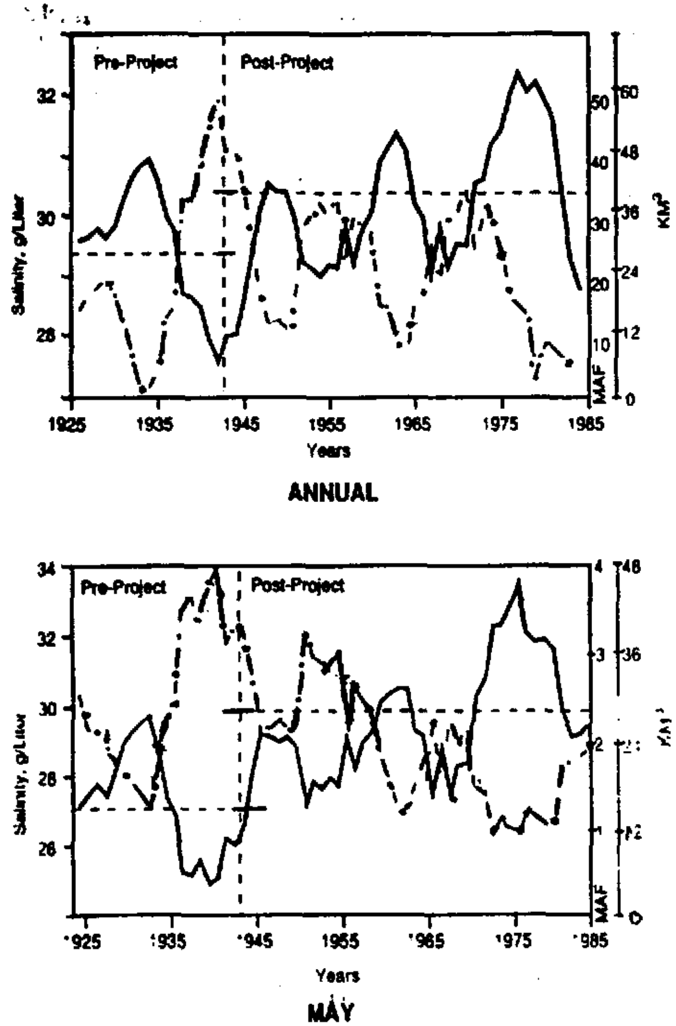

Figure 5. Chronological fluctuations of the 5-Year running mean delta outflow and salinity of surface water at the Golden Gate Bridge, San Francisco Bay (NOAA Database, 1925-85).

Since commencement of regulated runoff in the former Soviet Union, the annual unimpaired runoff has been reduced to 68% (Volga), 40 to 50% (Dniester, Dnieper and Don), 15 to 20% (Kuban) and down to 0.5 to 3% (Amu-Darya and Syr-Darya) of their norms (Rozengurt, 1991). As a result, the number of man-induced, subnormal, dry, and drought years have occurred 60 to 95% of the time as compared to unimpaired runoffs. This means that thousands of cubic kilometers of freshwater have been denied access to the detriment of the most productive coastal ecosystems.

Second. Estuaries have evolved for thousands of years and acquired terrestrial runoff from watersheds and coastal seas' regime characteristics. Therefore, they may be conceptually perceived as an ecological continuum of rivers into adjacent coastal seas. Hence, their unique diversity of water masses had been maintained foremost by renewable, unimpaired but limited and variable fresh water inflow. The work done by natural discharges, *regardless of the hydrophysical, geophysical, and morphometric differences* of estuaries, had been responsible for the intensity of advection, mixing and spatial-temporal displacement of their hydrophysical and biological characteristics at the optimal levels necessary to sustain the survival of the specific biota of such ecosystems (Bowden 1983, Kennish, 1986). Only during short periods (hours or several days) could tidal effects and aperiodic wind stress abnormally compound continuous mixing and movement of these fluxes. However, on a time scale of a month or a year these periodic and aperiodic disturbances are smoothed out.

That is why only unimpaired monthly and annual runoffs that affect an average salinity of estuaries should be taken into account for a probability analysis. The latter will provide for prognosis of the possible effects of planned diversions and cumulative losses of runoffs on ecological vitality of coastal systems. For example, since the late 1960s, in the former U.S.S.R., 30 major and hundreds of small dams have retained 60 to 97% of spring freshwater flux into these seas. As a result, the fresh water deficit has *already exceeded many dozens or even hundreds of the times of volumes of* estuaries and bays. Subsequently, their functioning has been largely destroyed or is at the brink (Petts, 1984, Rozengurt, 1992, Zaitsev and Mamaev, 1997).

Note that thousand miles of channels and underground pipelines, together with 49 small and large dams and 57 man-made reservoirs built in the Colorado watershed have turned the lower river into a shallow channel where remnants of regulated flow are too weak to revitalize or stop the desertification of the Colorado delta.

Third. Historically, unobstructed water and salt exchange between rivers and their adjacent seas preserved a rather intricate, quasi-equilibrium regime of estuaries, for fresh water fluxes serve as a physical barrier which repulse brackish or salt water intrusión into a delta. The seasonal alteration of runoff potential / kinematics energy input / output exerts a substantial force on deltaic, estuarine, and coastal circulation patterns (river plumes, coastal hydrofront). The higher unimpaired runoff, the more its energy output which, in turn, accelerates horizontal and vertical mixing and a powerful *frictional drag. The latter are responsible for the entrainment* of estuarine waters whose spring discharges, in particular, can be up to 10 to 100 times greater than that of the river flood itself (Mann, 1982). This complex phenomenon sets in motion a mixed estuarine flux toward the coastal seas where it can occupy a large area typified by gray - brownish color and the demarcation line known as a hydrofront. One of the major tasks of this water body is to lessen the extremes of landward marine water intrusion and preserve a quasi-dynamic equilibrium within an estuary of four delineated interactive zones as well as sand bars and beaches. The different ratios of *unimpaired entrainment* maintain the regime of estuarine reaches suitable for nearly fresh to brackish water biota and, in addition, controls entirely community production and respiration and the endurance of estuarine - coastal sea ecosystems as a whole.

The stage of dynamic equilibrium of any type of estuary for mean sea level can be described by the following water and salt balance equations (Lauff, 1967, Officer, 1976, Rozengurt and Tolmazin, 1974):

$$W_1S_1 = W_2S_2 \qquad (1)$$

where $$W_1 = N + W_2 \qquad (2)$$

or $$S_1 = (W_2S_2)/(P+R-E+W_2) \qquad (3)$$

and $$S_E = f(R, S_1) \qquad (4)$$

Where: $N = P+R-E$ - the component of fresh water balance of an estuary, km^3; P - precipitation and E - evaporation over a surface of an estuary; R - river runoff; W_1 - the estuarine "buffer" outflow; W_2 - the sea inflows, km^3; $W_1 > W_2$ (*for unimpaired runoff*): S_1 *and* S_2 - *the salinity of the estuarine* outflow and coastal sea inflow, $S_2 > S_1$; S_E - average weighted salinity (a gram per liter) of the estuary. However, in the case in which diversions, vR, have already begun, N -vR; S_E can be evaluated from (Rozengurt, 1971, 1974):

$$S_{E(n)} = S_{E(n-1)} \pm vS_{E(n)} \qquad (5)$$

Where $S_{E(n-1)}$ is the salinity of the preceding year, $\pm vS_{E(n)}$ - the cumulative increment *of salinity of a given year, n, due to* salt water intrusion, $S_{E(n)}$ - is the accumulative average weighted salinity of an estuary for "n" year.

This scheme hides some features of an exceedingly complex process of salt accumulation in estuaries but it outlines the following major regularities: (1)

diversions lead to a gradual decrease of **N and** W_1 and increase W_2 ; S_2 ; S_1 and S_E (Figure 5); (2) $\pm vS_{E(n)}$ **will fluctuate until diversion takes place; (3)** $vS_{E(n)} \approx 0$, **if diversions have paused, and** S_E **tends to reach its dynamic equilibrium within a definite period; (4) if diversions proceed to increase,** ***salt pollution will be intensified until a stable salt concentration is reached,*** and (5) If $R < P-E$, then $W_1 \approx W_2$, $S_1 \approx S_2$ and $S_{E(n)}$ **will tend to be slightly higher then** S_1 **due to the effect of evaporation.** Thus, under impaired flow the balanced coexistence between a river, delta, estuary, and coastal embayment begins to falter and, if $R \approx 0$, then with time an estuary will be transformed into a salty marine embayments, **where** $S_E > S_1 > S_2$ **- means a partial or fully distorted "equilibrium,"** phenomenon that has negatively influenced numerous aquatic ecosystems whose salinity has increased up to two fold and adjacent coastal seas up to 1.5 to 2.0 times (for example, the north-western part of the Black sea and Sea of Azov, respectively).

Moreover, the natural intensity and duration of the spring flood that used to extend up to 40 days have dropped two to three fold. This has further exacerbated salinization of deltas up to the point when water is unsuitable for humans' needs or to support the continuation of the reproductive cycle for living resources or, both. In some extent, these processes of gradual destabilization and despoliation have been documented in many impounded ecosystems: San Francisco, Florida, and Chesapeake bays, Gulf of Mexico's estuaries, Colorado, and Nile Deltas. On the Nile artificial disruption of *seasonal and annual flows occurred on a scale much higher than in several* natural catastrophic droughts during the first half of the past twenty centuries (Halim, 1991, Rozengurt and Haydock, 1993).

Fourth. Deltas and estuaries are remarkably resilient to naturally intrinsic and extrinsic disturbances triggered by the volume and timing of freshwater inflow from their watersheds. Under normal conditions, the delta as a heart of an estuarine system, receives ionic and organic and inorganic constituents from a watershed. And, what is more important, filters pollutants and produce, circulate, process, and discharge about 70% nutrient increment into the brackish water body of an estuary (Almazov, 1962). As a result, these composite process determine the vitality and recuperative properties and the biological self-adjustment and rich productivity of estuary- coastal sea habitats. (Kennish, 1986, Mann, 1982).

However, seventy percent of U.S. rivers and streams have been damaged by human-induced flow changes (Baker, 1994). That is why the desiccation of river bed, compounded by formidable, cumulative losses of water and chemical elements, have made "restoration" projects such as the releases of millions of fry reared in hatcheries, or occasional sanitary water discharges from dams, too costly and ineffective. The historical habitats have experienced chronic freshwater deficit and life gradually changed beyond recognition (Kemp et al., 1984, Hinman, 1991).